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Baldasarre et al.

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(54) **MEMS ACCELEROMETER WITH PROOF MASSES MOVING IN ANTI-PHASE DIRECTION NORMAL TO THE PLANE OF THE SUBSTRATE**

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G01P 3/44	(2006.01)
G01C 19/56	(2012.01)

(52) **U.S. Cl.**
CPC ***G01C 19/56*** (2013.01)
USPC **73/504.12**

(58) **Field of Classification Search**
USPC 73/514.12
See application file for complete search history.

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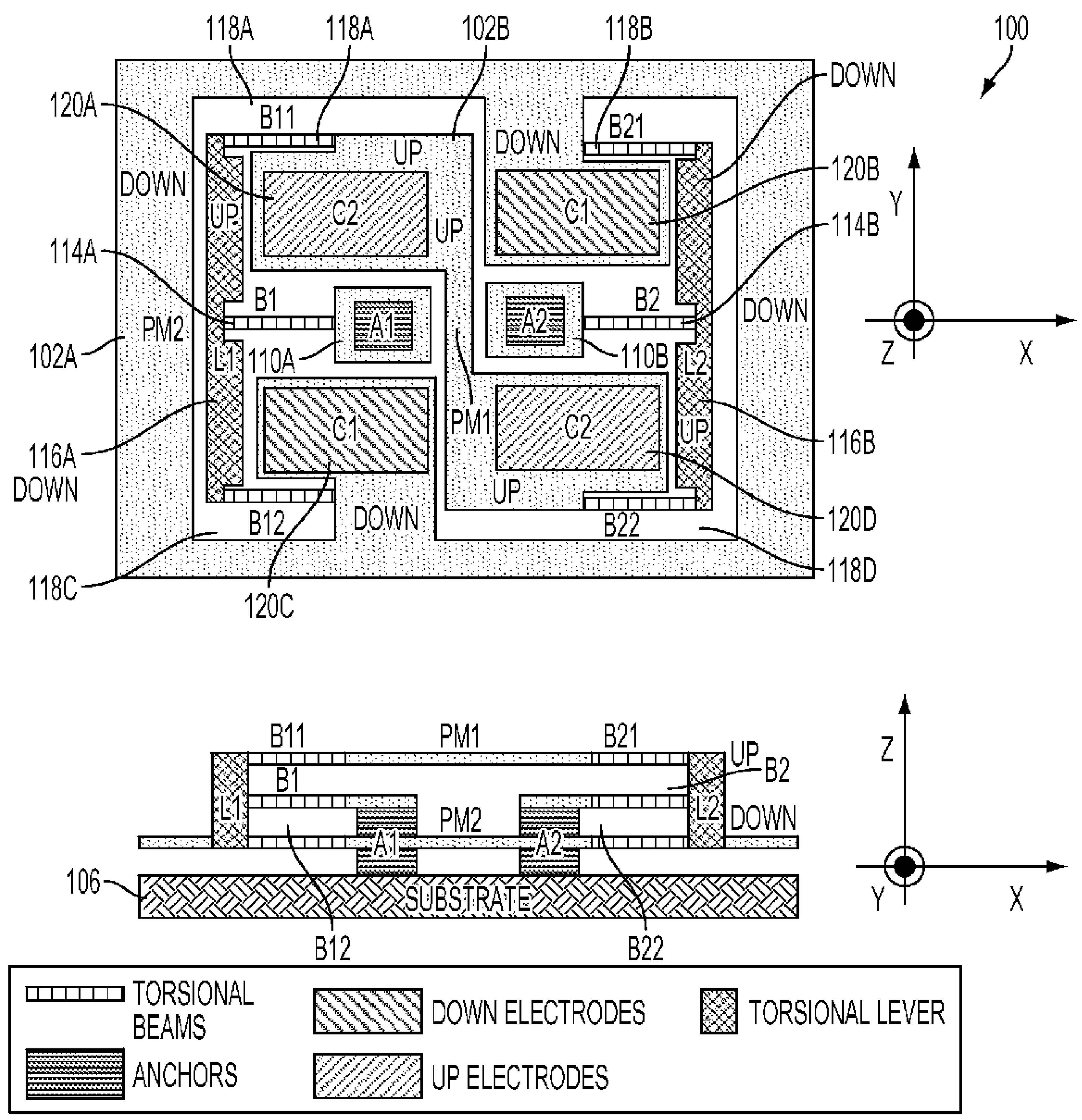
(57) **ABSTRACT**

A sensor is disclosed. The sensor includes a substrate and at least two proof masses. The sensor also includes a flexible coupling between the at least two proof masses and the substrate. The at least two coupling proof masses move in an anti-phase direction normal to a plane of the substrate in response to acceleration.

22 Claims, 13 Drawing Sheets



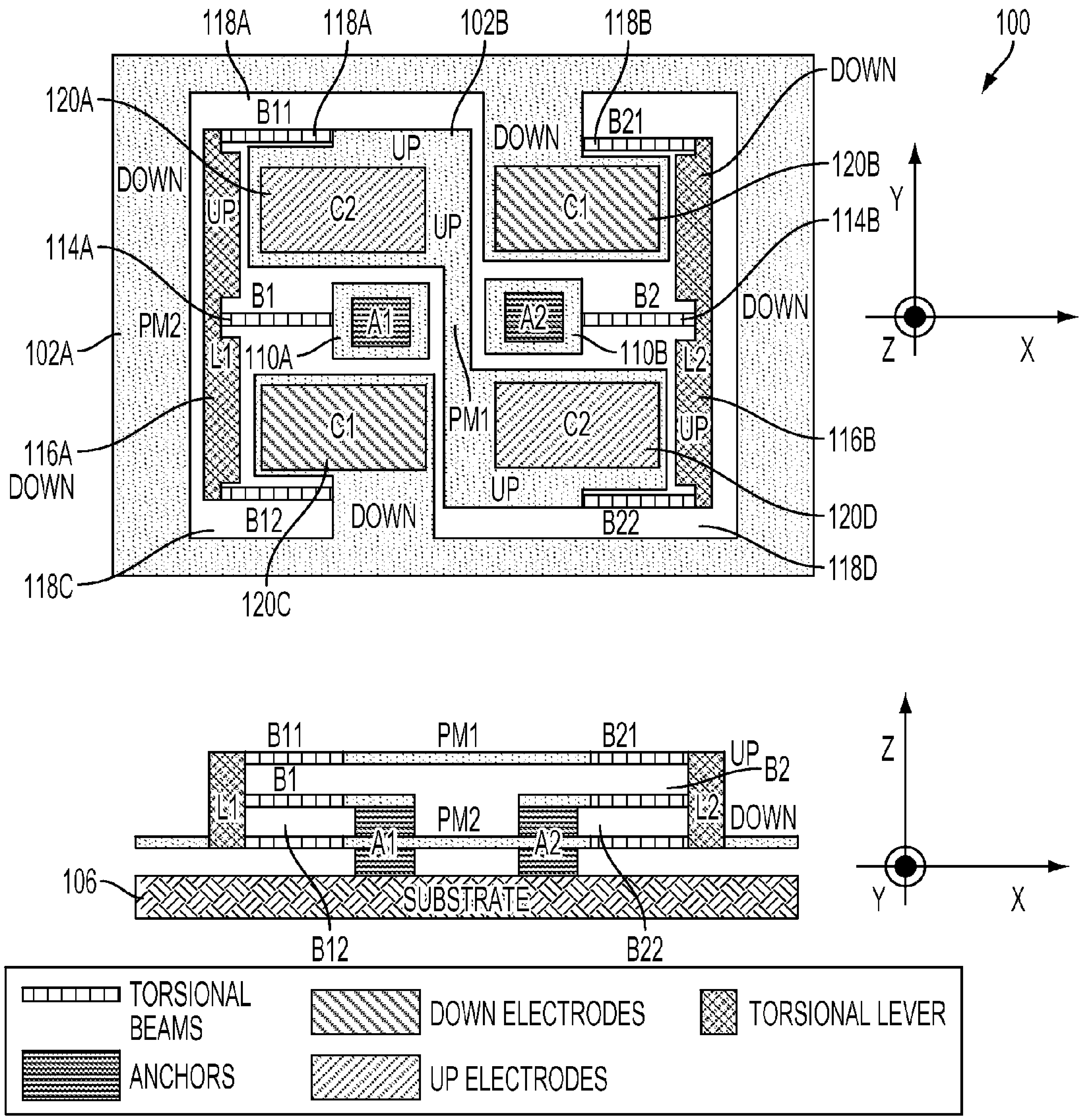

100
118A
118A
102B
118B
DOWN
120A
B11
UP
DOWN
B21
120B
DOWN
UP
C2
UP
C1
114B
114A
B1
A1
A2
B2
DOWN
PM2
110A
110B
102A
L1
PM1
L2
C1
C2
UP
116A
116B
DOWN
UP
B12
DOWN
B22
120D
118C
118D
120C
Y
Z
X
B11
PM1
B21
UP
B2
B1
L1
PM2
L2
DOWN
A1
A2
106
SUBSTRATE
B12
B22
Z
Y
X
TORSIONAL BEAMS
DOWN ELECTRODES
TORSIONAL LEVER
ANCHORS
UP ELECTRODES

FIG. 1

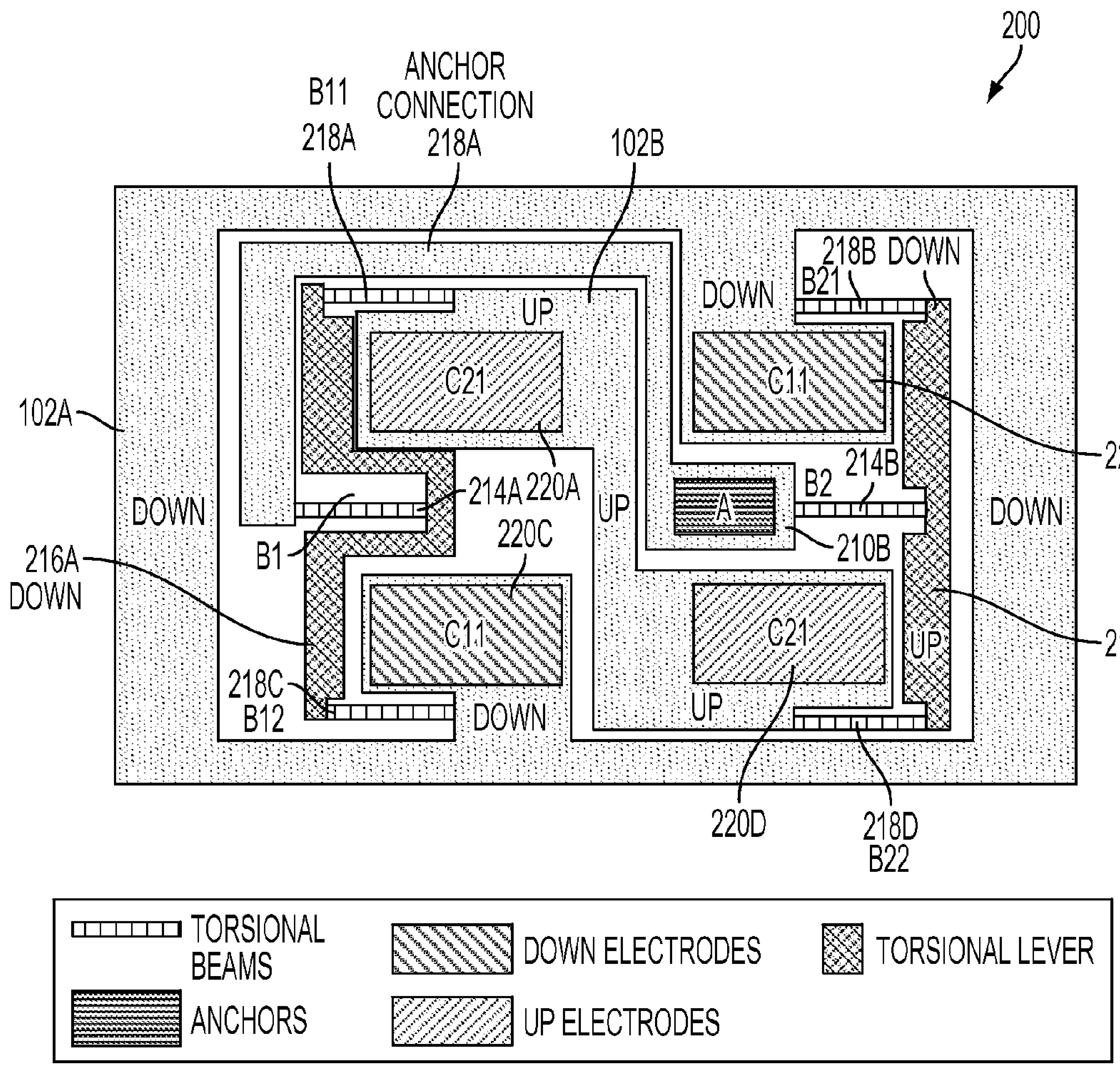

200
B11
218A
ANCHOR
CONNECTION
218A
102B
218B
DOWN
B21
DOWN
UP
C21
C11
220B
102A
DOWN
214A
220A
UP
A
B2
214B
DOWN
B1
220C
210B
216A
DOWN
C11
C21
216B
UP
218C
B12
DOWN
UP
220D
218D
B22
TORSIONAL
BEAMS
DOWN ELECTRODES
TORSIONAL LEVER
ANCHORS
UP ELECTRODES

FIG. 2

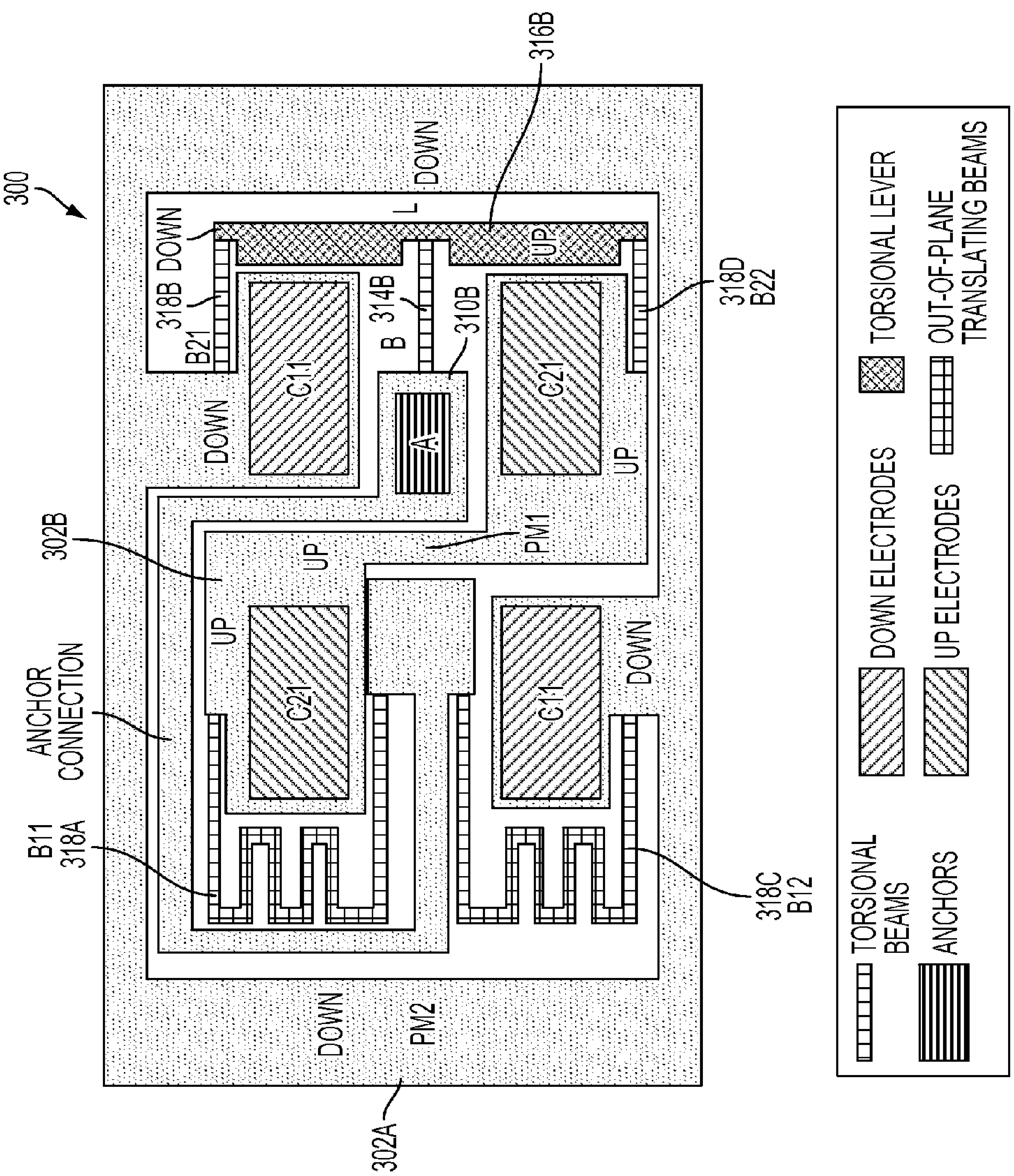

300
316B
DOWN
L
UP
318B DOWN
B21
314B
B
310B
C11
C21
A
DOWN
UP
318D
B22
302B
UP
PM1
UP
C21
C11
DOWN
ANCHOR
CONNECTION
B11
318A
318C
B12
DOWN
PM2
302A
TORSIONAL
BEAMS
ANCHORS
DOWN ELECTRODES
UP ELECTRODES
TORSIONAL LEVER
OUT-OF-PLANE
TRANSLATING BEAMS

FIG. 3

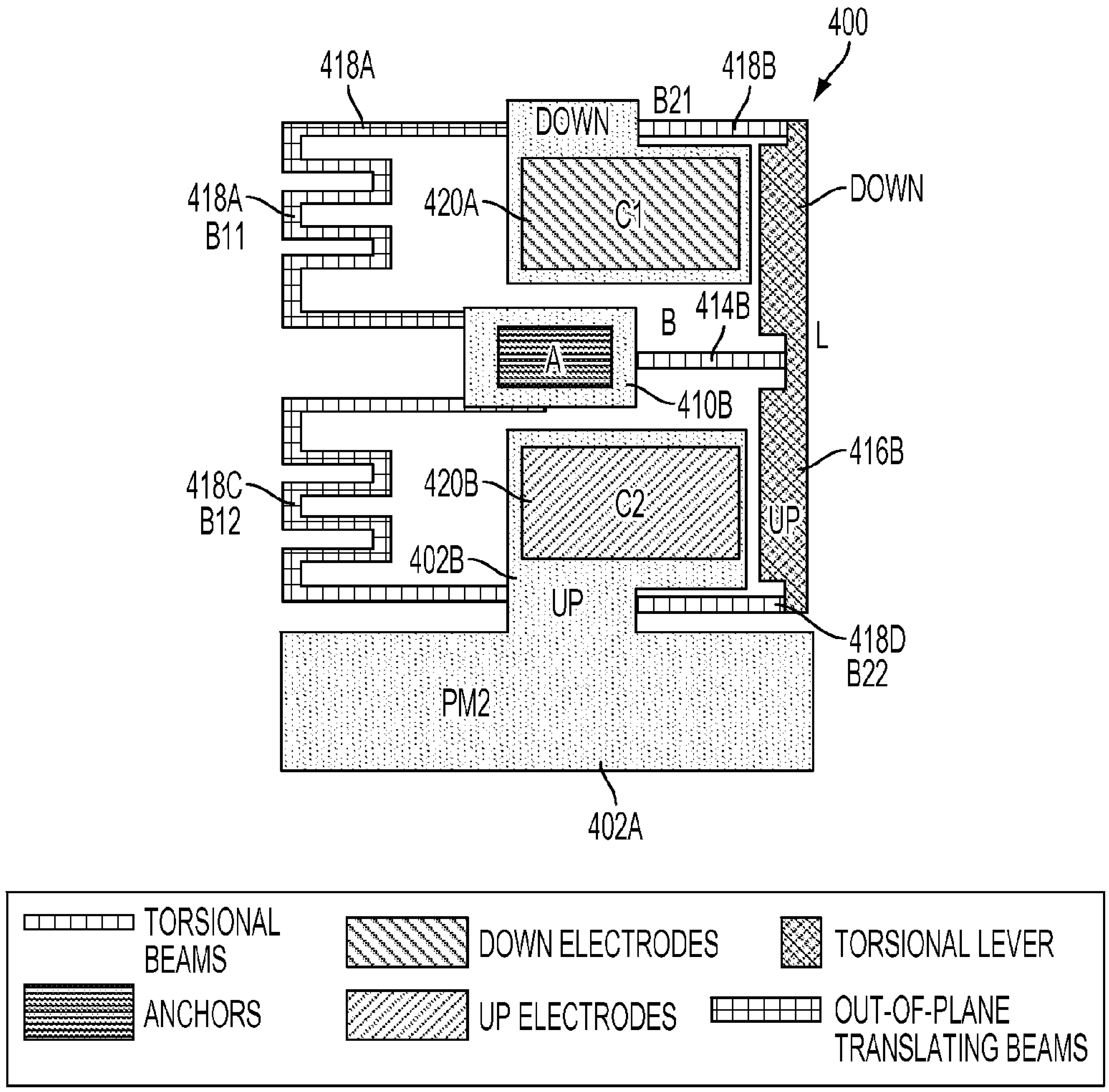

400
418A
418B
B21
DOWN
DOWN
418A
B11
420A
C1
B
414B
L
A
410B
416B
418C
B12
420B
C2
UP
402B
UP
418D
B22
PM2
402A
TORSIONAL BEAMS
DOWN ELECTRODES
TORSIONAL LEVER
ANCHORS
UP ELECTRODES
OUT-OF-PLANE TRANSLATING BEAMS

FIG. 4

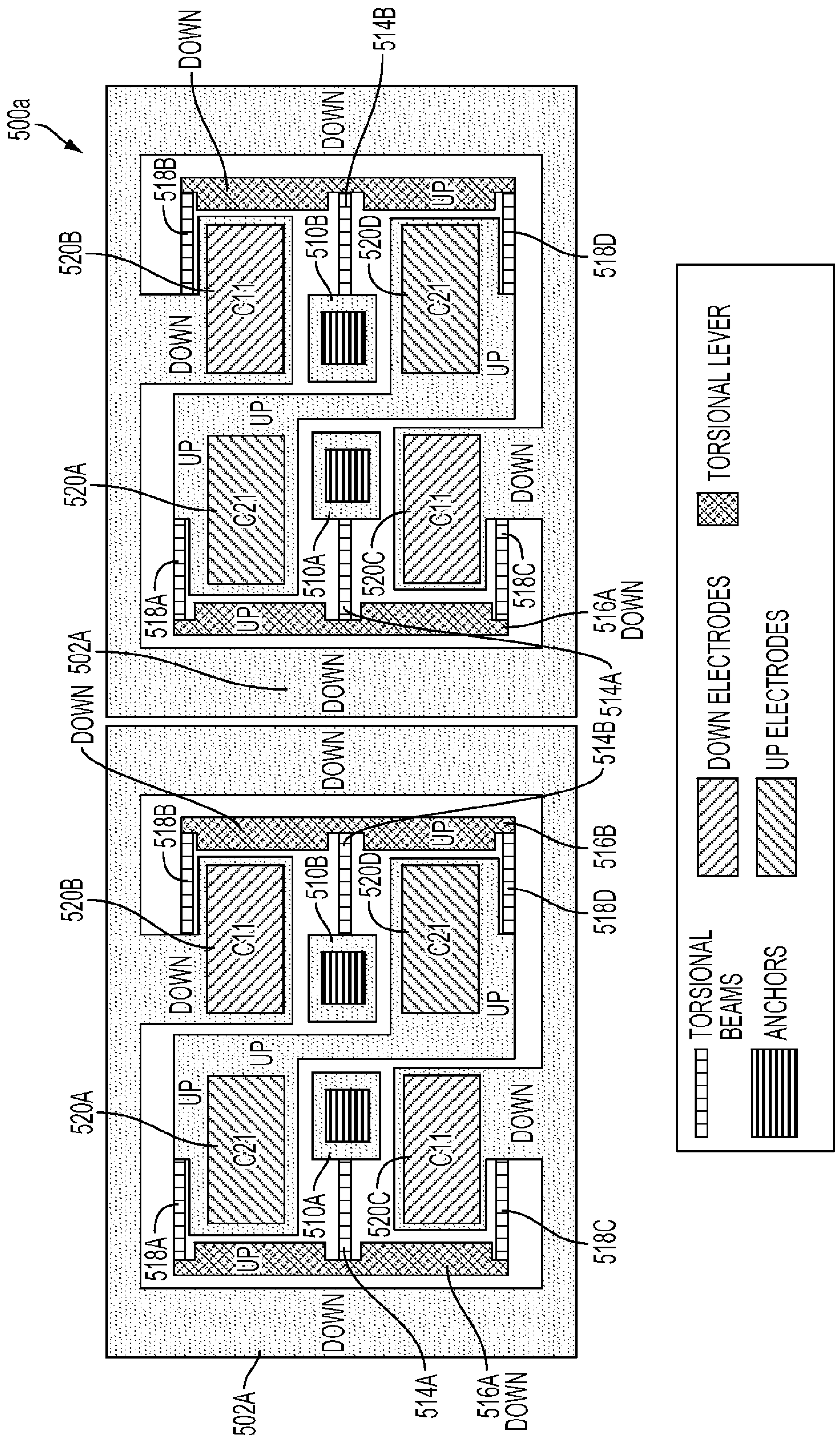

500a
DOWN
514B
518B
520B
510B
520D
518D
C11
C21
UP
DOWN
520A
518A
510A
520C
518C
516A
514A
502A
516B
TORSIONAL BEAMS
ANCHORS
DOWN ELECTRODES
UP ELECTRODES
TORSIONAL LEVER

FIG. 5a

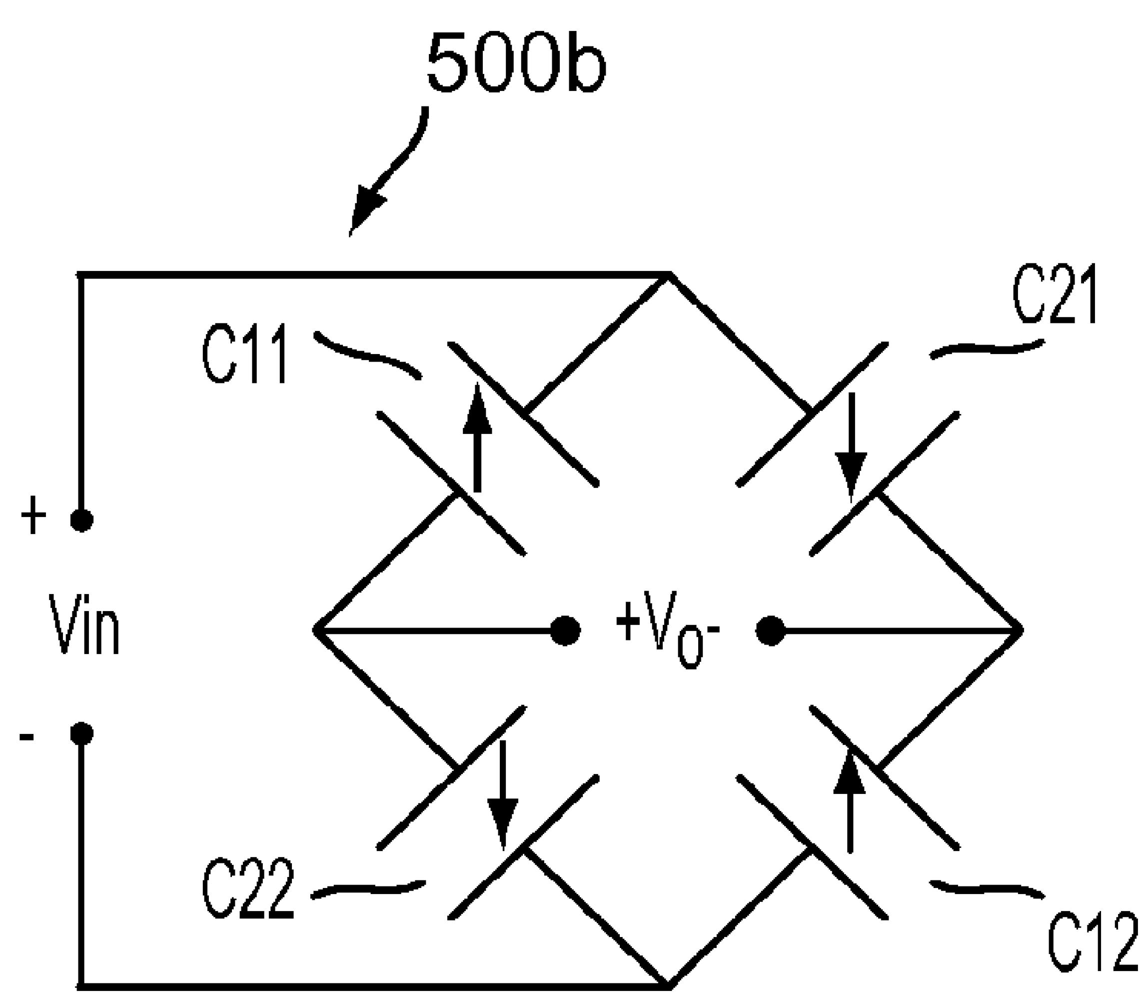


FIG. 5(b)

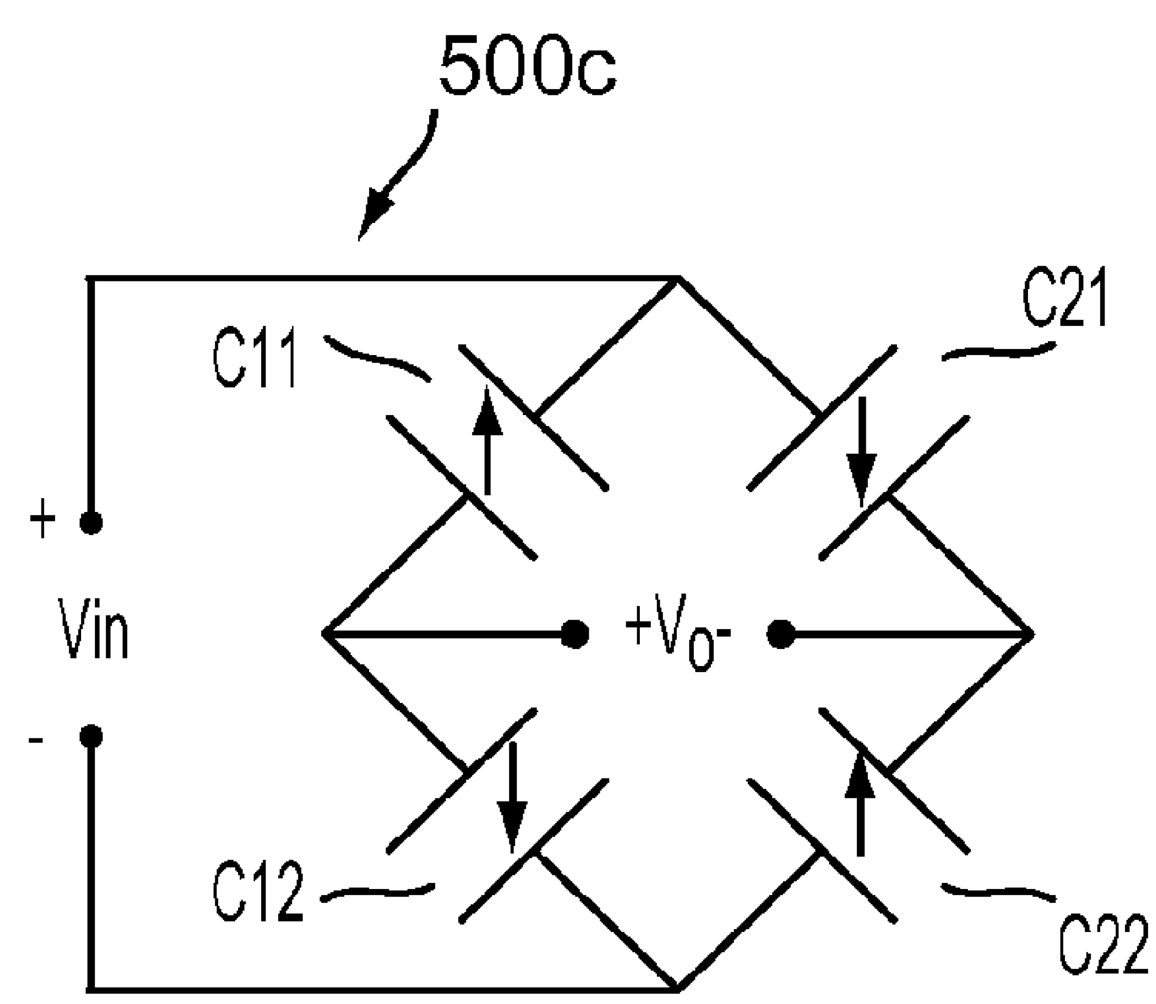


FIG. 5(c)

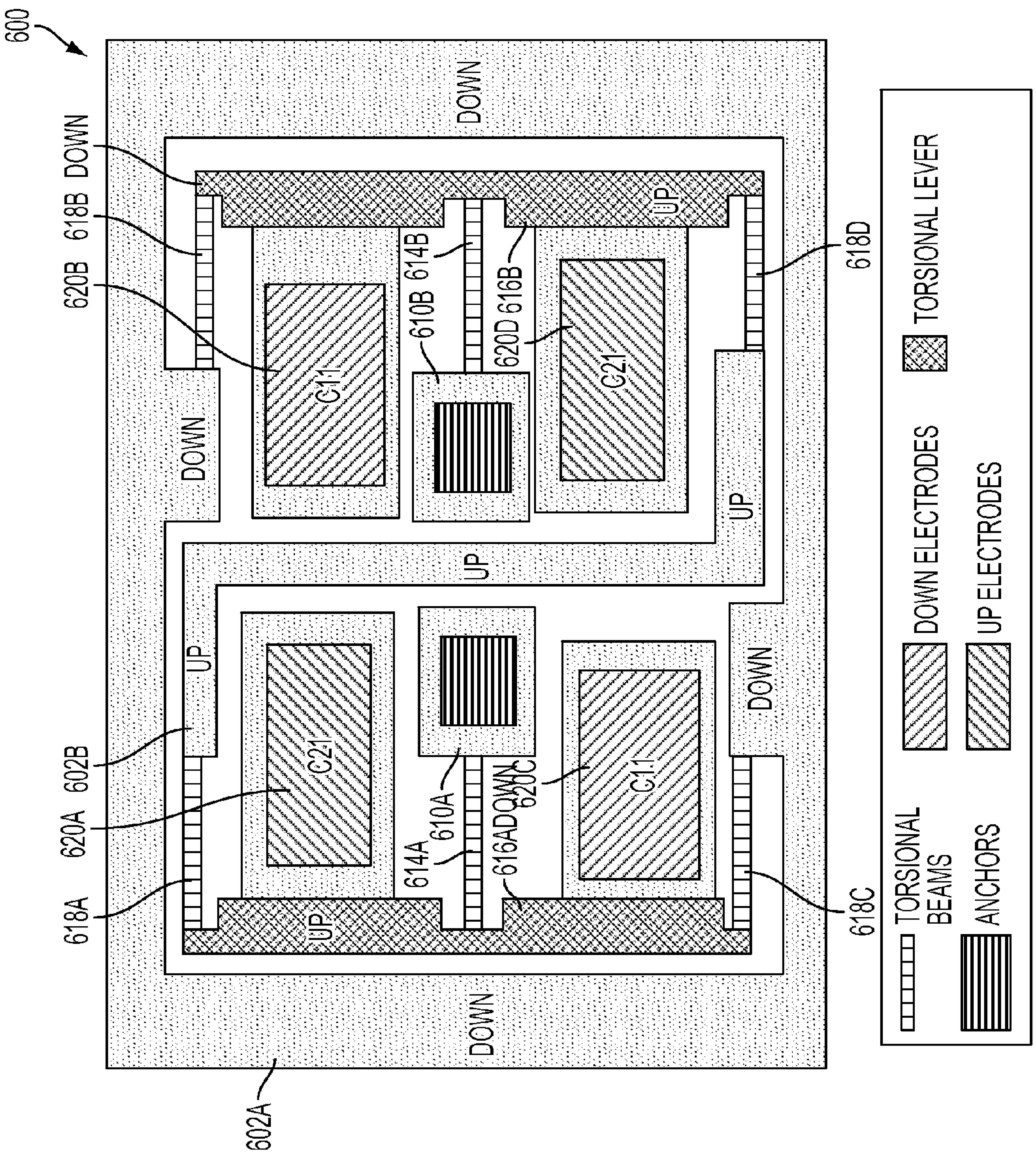

600
DOWN
620B
618B
DOWN
610B
614B
620D
616B
618D
C11
C21
UP
602B
620A
618A
614A
610A
616A
DOWN
620C
618C
602A
TORSIONAL BEAMS
ANCHORS
DOWN ELECTRODES
UP ELECTRODES
TORSIONAL LEVER

FIG. 6

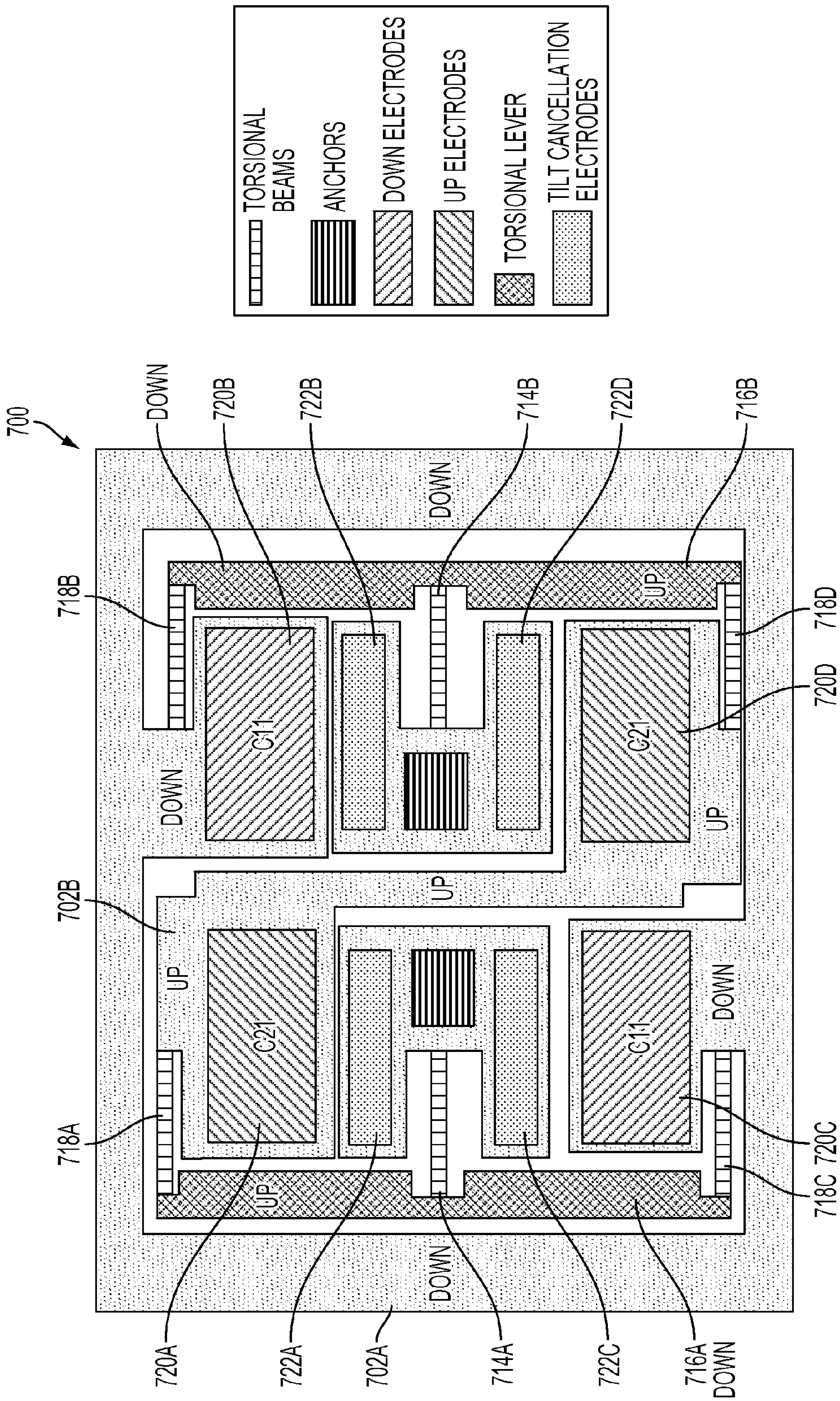
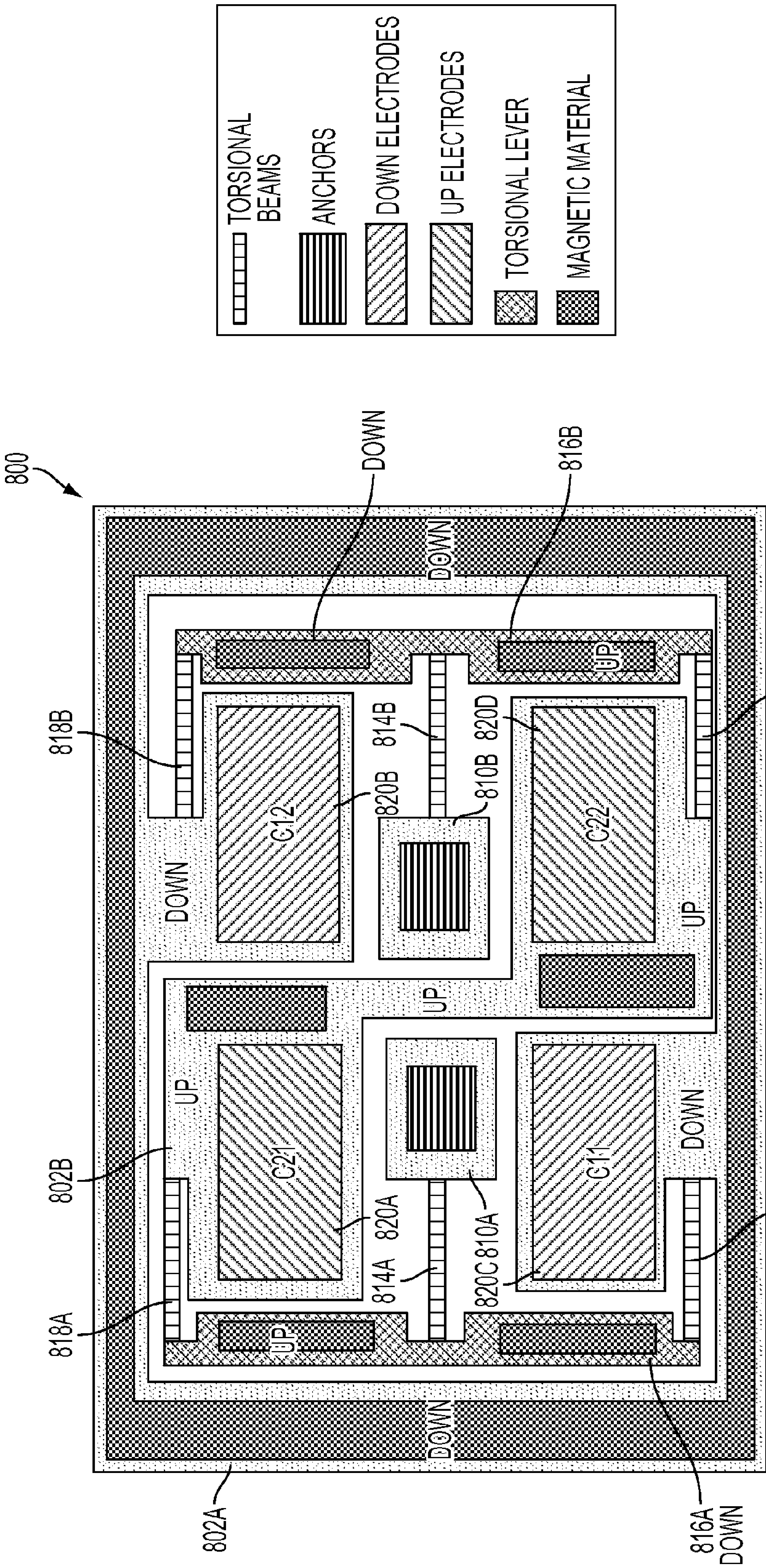

TORSIONAL BEAMS
ANCHORS
DOWN ELECTRODES
UP ELECTRODES
TORSIONAL LEVER
TILT CANCELLATION ELECTRODES
700
DOWN
720B
722B
714B
722D
716B
718B
718D
720D
702B
718A
718C
720C
720A
722A
702A
714A
722C
716A
C11
C21
UP

FIG. 7



TORSIONAL BEAMS
ANCHORS
DOWN ELECTRODES
UP ELECTRODES
TORSIONAL LEVER
MAGNETIC MATERIAL
800
DOWN
816B
818B
818D
814B
820D
820B
810B
C12
C22
DOWN
UP
UP
UP
802B
C21
C11
DOWN
818C
820A
814A
820C
810A
818A
UP
DOWN
802A
816A
DOWN

FIG. 8

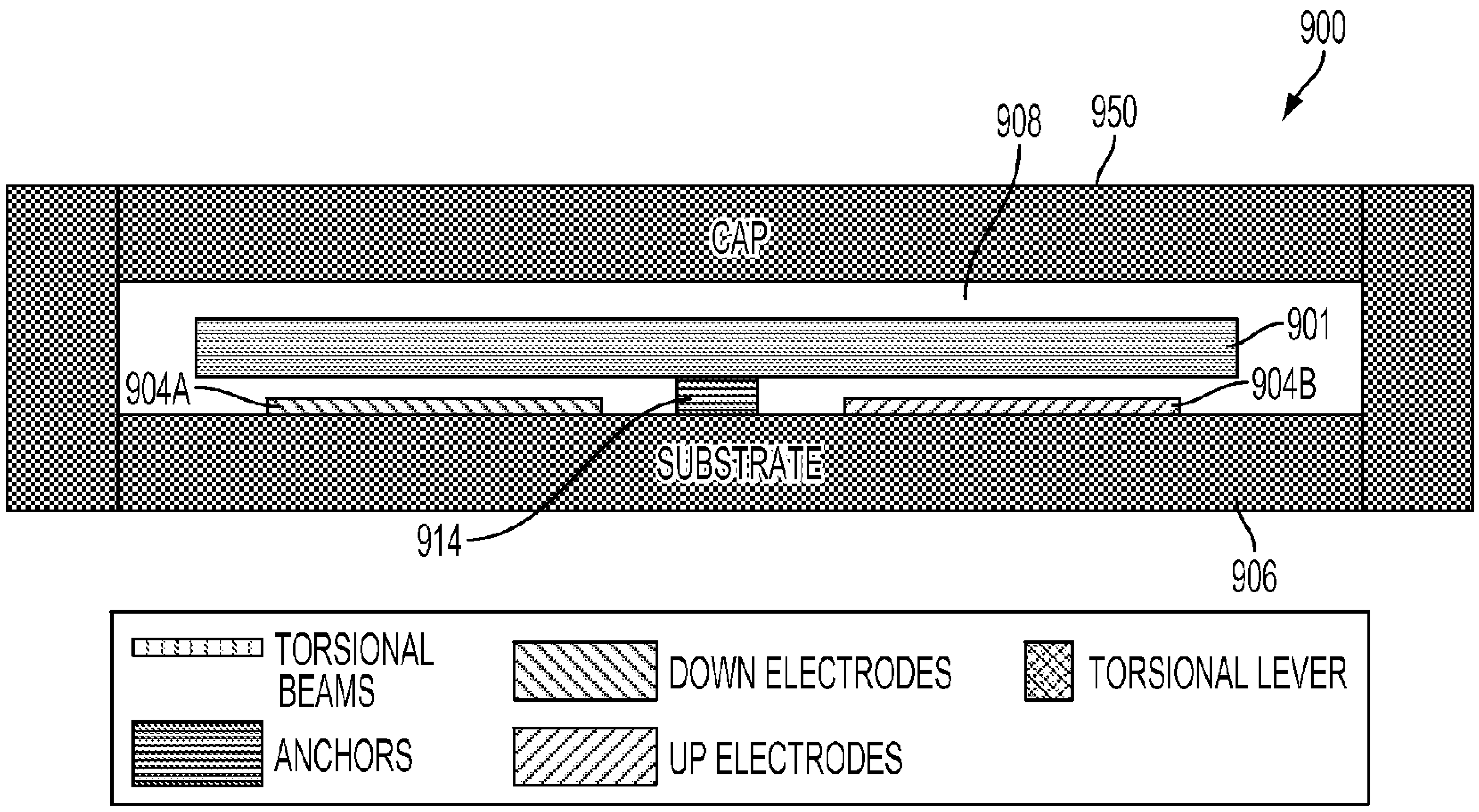

900
908
950
CAP
901
904A
904B
SUBSTRATE
914
906
TORSIONAL BEAMS
DOWN ELECTRODES
TORSIONAL LEVER
ANCHORS
UP ELECTRODES

FIG. 9

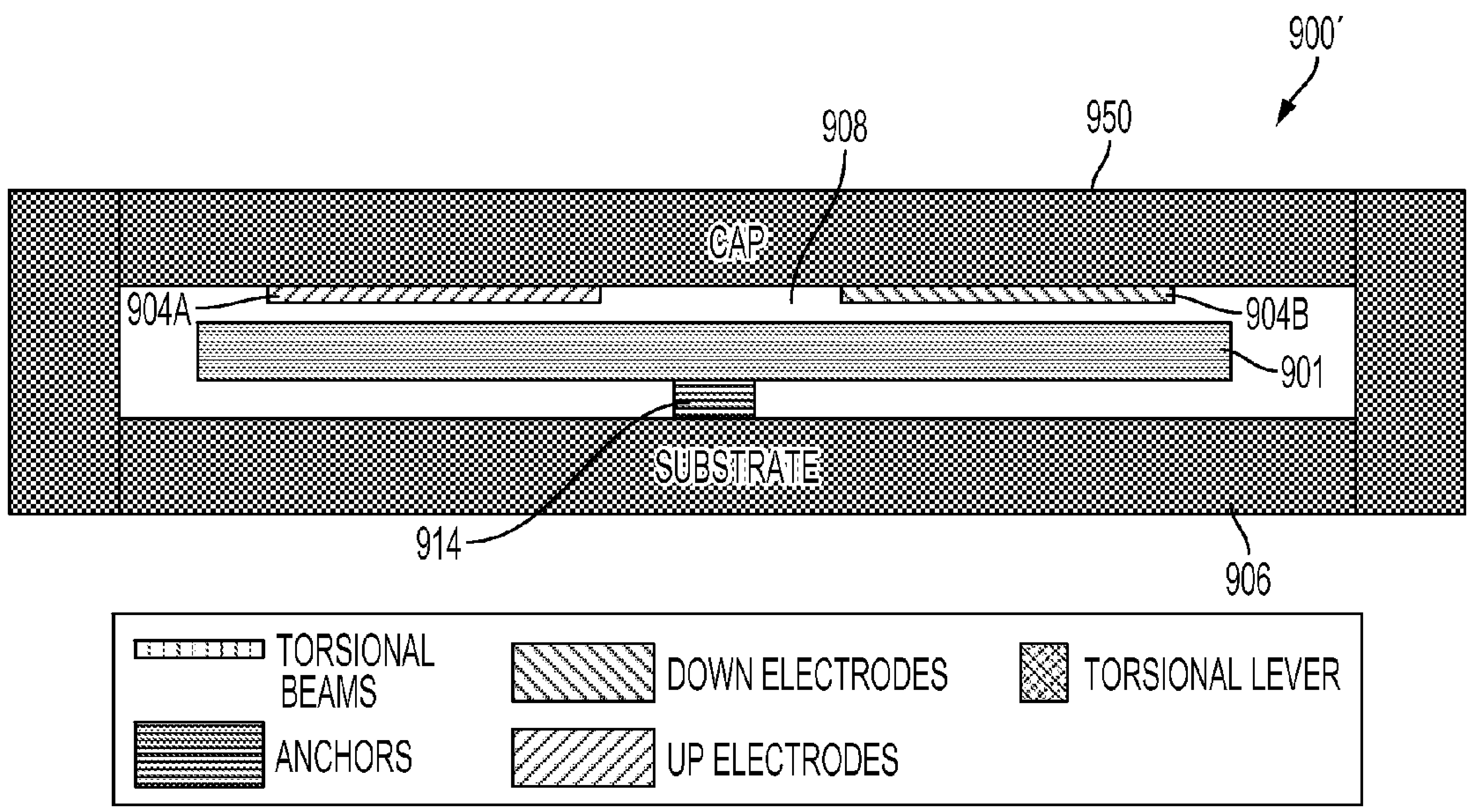

900′
908
950
CAP
904A
904B
901
SUBSTRATE
914
906
TORSIONAL BEAMS
DOWN ELECTRODES
TORSIONAL LEVER
ANCHORS
UP ELECTRODES

FIG. 10

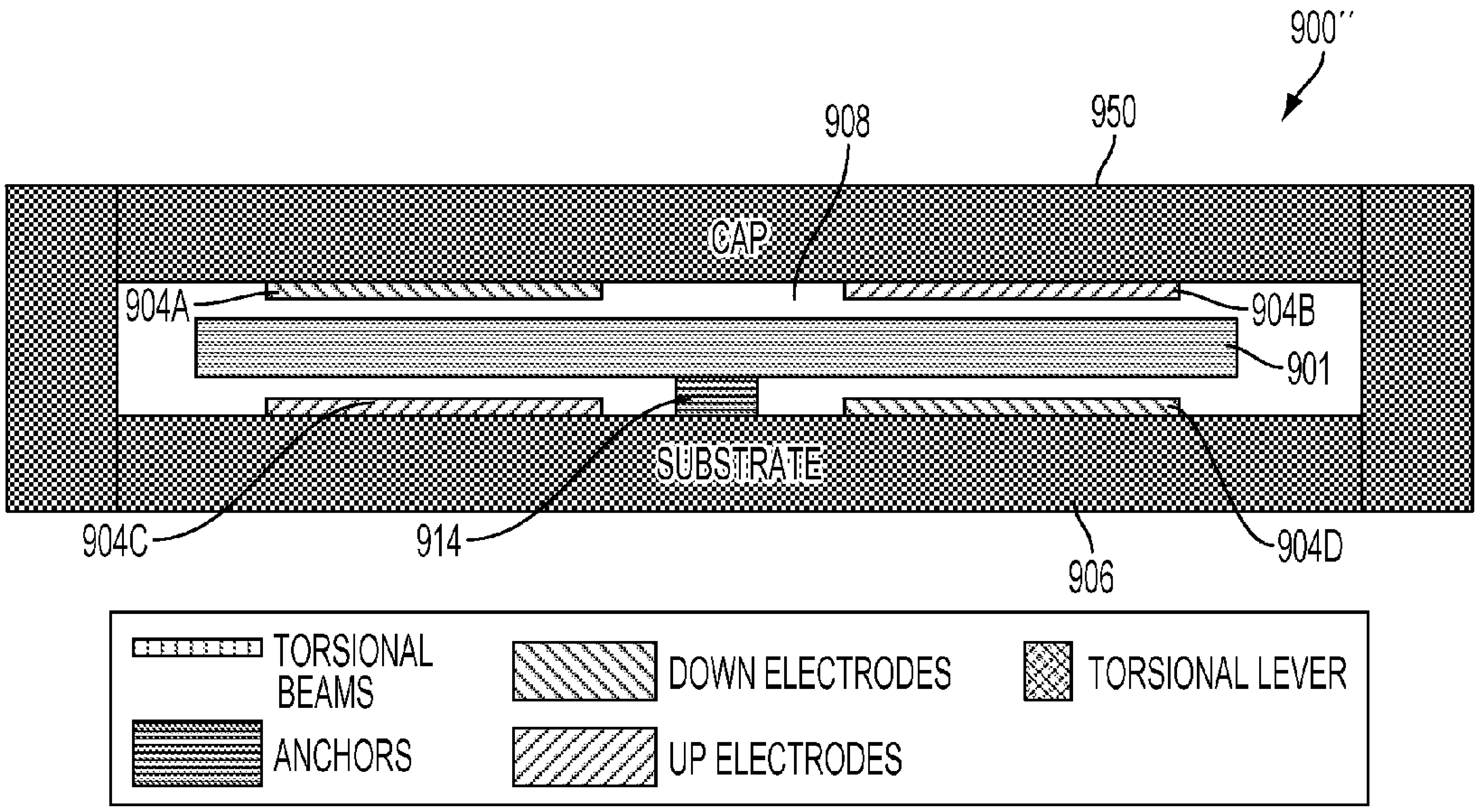

900''
908
950
CAP
904A
904B
901
SUBSTRATE
904C
914
906
904D
TORSIONAL BEAMS
DOWN ELECTRODES
TORSIONAL LEVER
ANCHORS
UP ELECTRODES

FIG. 11

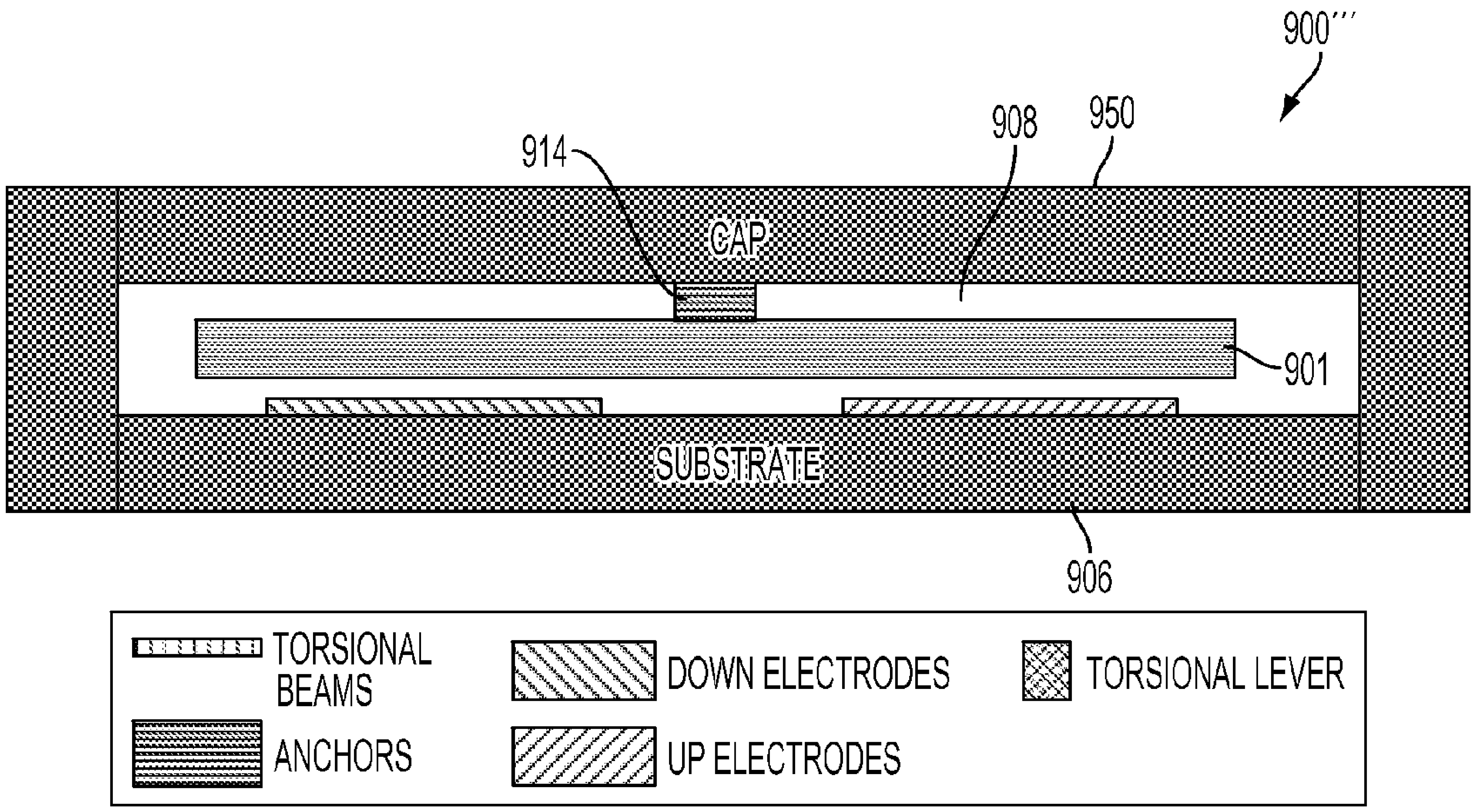

900'''
914
908
950
CAP
901
SUBSTRATE
906
TORSIONAL BEAMS
DOWN ELECTRODES
TORSIONAL LEVER
ANCHORS
UP ELECTRODES

FIG. 12

MEMS ACCELEROMETER WITH PROOF MASSES MOVING IN ANTI-PHASE DIRECTION NORMAL TO THE PLANE OF THE SUBSTRATE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims benefit under 35 USC 119(e) of U.S. Provisional Patent Application No. 61/920,246, filed on Dec. 23, 2013, entitled "MEMS ACCELEROMETER WITH PROOF MASSES MOVING IN ANTI-PHASE DIRECTION NORMAL TO THE PLANE OF THE SUBSTRATE," which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates generally to inertial sensors and more particularly to MEMS accelerometers.

BACKGROUND

Inertial sensors such as accelerometers are widely used for motion sensing applications. Conventionally, an accelerometer consists of a suspended proof mass and a means of measuring the proof mass displacement with respect to the reference frame. There is always a need to provide improvements in the performance and reliability of an accelerometer for commercial applications. Typically, performance is determined by the mechanical and electrical sensitivities of the sensor and reliability is determined, among many other parameters, by the required breakout force to unstuck moving parts of the structure in case of accidental contact with other fixed or moving parts.

What is needed therefore is a system and method that provides such inertial sensors. The method and system should be easily implemented, cost effective and adaptable to existing environments. The present invention addresses the above-identified issues.

SUMMARY

A sensor is disclosed. In a first aspect, the sensor includes a substrate and at least two proof masses. The sensor also includes a flexible coupling between the at least two proof masses and the substrate. The at least two coupling proof masses move in an anti-phase direction normal to a plane of the substrate in response to acceleration.

In a second aspect, a combined accelerometer and a magnetometer includes a substrate and at least two proof masses. The combined accelerometer and the magnetometer also includes a flexible coupling between the two proof masses and the substrate. The proof masses move in an anti-phase direction normal to a plane of the substrate in response to acceleration. The combined accelerometer and the magnetometer also includes a magnetic material that causes the combined accelerometer and magnetometer to rotate around a first axis in response to a magnetic field. The acceleration and magnetic field can be sensed separately because they have two different sensing modes, respectively the anti-phase movement of the proof masses and the tilting around the first axis of the proof masses. For instance outputs of the combined accelerometer and magnetometer can be measured by altering the configuration of transducer to sense separate the outputs given by the acceleration and magnetic field.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an accelerometer that responds to a linear acceleration in a Z direction.

FIG. **2** shows a single anchor accelerometer in accordance with an embodiment.

FIG. **3** shows a single lever and single anchor accelerometer in accordance with an embodiment.

FIG. **4** shows an alternative single lever accelerometer in accordance with an embodiment.

FIG. **5***a* shows the configuration of the sensor to be a capacitive wheatstone bridge in accordance with an embodiment.

FIG. **5***b* shows a configuration for sensing acceleration in a Wheatstone bridge configuration as shown in accordance with an embodiment.

FIG. **5***c* shows a configuration for sensing magnetic field in a Wheatstone bridge configuration as shown in accordance with an embodiment.

FIG. **6** shows an accelerometer where a capacitive readout is performed on a rotational lever instead on proof masses in accordance with an embodiment.

FIG. **7** shows an accelerometer including the tilt cancellation paddles in accordance with an embodiment.

FIG. **8** shows a combined accelerometer and magnetometer sensor in accordance with an embodiment.

FIGS. **9-12** show a various embodiments of sensors that includes a cap as part thereof.

DETAILED DESCRIPTION

The present invention relates generally to inertial sensors and more particularly to MEMS accelerometers. The following description is presented to enable one of ordinary skill in the art to make and use the invention and is provided in the context of a patent application and its requirements. Various modifications to the preferred embodiments and the generic principles and features described herein will be readily apparent to those skilled in the art. Thus, the present invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features described herein.

In the described embodiments micro-electro-mechanical systems (MEMS) refers to a class of structures or devices fabricated using semiconductor-like processes and exhibiting mechanical characteristics such as the ability to move or deform. MEMS devices often, but not always, interact with electrical signals. MEMS devices include but are not limited to gyroscopes, accelerometers, magnetometers, pressure sensors, microphones, and radio-frequency components. Silicon wafers containing MEMS structures are referred to as MEMS wafers.

In the described embodiments, the MEMS device may refer to a semiconductor device implemented as a micro-electro-mechanical system. The MEMS structure may refer to any feature that may be part of a larger MEMS device. The semiconductor layer with the mechanically active MEMS structure is referred to as the device layer. An engineered silicon-on-insulator (ESOI) wafer may refer to a SOI wafer with cavities beneath the silicon device layer or substrate. A handle wafer typically refers to a thicker substrate used as a carrier for the thinner silicon device substrate in a silicon-on-insulator wafer. A handle substrate and a handle wafer can be interchanged.

In the described embodiments, a cavity may refer to an opening or recession in a substrate wafer and an enclosure may refer to a fully enclosed space. A post may be a vertical structure in the cavity of the MEMS device for mechanical support. A standoff is a vertical structure providing electrical contact.

In the described embodiments, a rigid structure within a MEMS device that moves when subject to force may be referred to as a plate. Although rigid plates are preferred for the described embodiments, semi rigid plates or deformable membranes could replace rigid plates. Plates may comprise of silicon, silicon containing materials (e.g. poly-silicon, silicon oxide, silicon nitride), metals and materials that are used in semiconductor processes (e.g. aluminum nitride, germanium). A back plate may be a solid or perforated plate comprising at least one electrode. The electrode can be comprised of semiconductor process compatible conductive materials (e.g. poly-silicon, silicon, aluminum, copper, nickel, titanium, chromium, gold). The electrodes may have insulating films on one or more surfaces.

FIG. **1** shows top and side views of an accelerometer **100** that responds to a linear acceleration in a Z direction. The accelerometer **100** comprises two proof masses PM1 **102**B and PM2 **102**A that respond to a linear acceleration in the Z direction by moving in anti-phase direction normal to a plane of a substrate **106**. The anti-phase movement is constrained by a flexible coupling between the two proof masses PM1 **102**B and PM2 **102**A and the substrate **106**. The flexible coupling comprises two separated anchors A1 **110**A and A2 **110**B, two central torsional springs B1 **114**A and B2 **114**B, two rotational levers L1 **116**A and L2 **116**B and four external torsional springs B11 **118**A, B21 **118**B, B12 **118**C and B22 **118**D. The motion of the accelerometer **100** is measured by an out-of-plane transducer on the proof masses, for instance a set of capacitive differential electrode C1 and C2 **120**A-**120**D.

The springs B1 **114**A and B2 **114**B connect the anchors A1 **110**A and A2 **110**B to the levers L1 **116**A and L2 **116**B. The four external torsional springs B11 **118**A, B21 **118**B, B12 **118**C and B22 **118**D connect the end of one lever to the end of the other lever on the opposite side trough the two proof masses PM1 **102**B and PM2 **102**A. In particular spring B11 **118**A connects the top of the left lever L1 **116**A to internal proof mass PM1 **102**B that connects the bottom of the right lever L2 **116**B trough the spring B22 **118**D. In the same way the bottom of the left lever L1 **116**A is coupled to the top of the right lever L2 **116**B with the springs B12 **118**C and B22 **118**D.

For simplicity, suppose that the proof masses have the center of gravity on the axis of the central springs (B1 **114**A and B2 **114**B) and that the external springs (B12 **118**C, B21 **118**B, B11 **118**A and B22 **118**D) are coupled to the proof masses with the same distance from the center of gravity orthogonal to this axis. A more general case is described in the following.

A linear acceleration a in the Z direction will create a force in Z for each proof mass:

$$F_{PM_1}=m_1a$$

$$F_{PM_2}=m_2a$$

Where m_1 and m_2 are the masses of PM1 **102**B and PM2 **102**A respectively. On each proof mass half of this force acts on each one of the external springs, B11 **118**A and B22 **118**D for PM1 **102**B and B12 **118**C and B21 **118**B for PM2 **102**A. Finally this force is transferred on the extreme of the lever so in the center of the lever there is a torque that is the difference of this force times the lever of PM1 **102**B and PM2 **102**A:

$$M=\frac{m_1a}{2}\Big|_{PM1}-\frac{m_2a}{2}\Big|_{PM2}$$

where the lever length of PM1 l_{PM1} is the distance from the springs B11 **118**A to B1 **114**A and B22 **118**D to B2 **114**B and l_{PM2} is the distance from the springs B12 **118**C to B1 **114**A and B21 **118**B to B2 **114**B. The torque M causes the central springs and the two levers to rotate in anti-phase and so one proof mass moves towards the substrate and the other moves in the opposite direction.

In order to cause the anti-phase movement there must be an unbalancing torque M. This unbalanced torque M can be given by a difference in the mass ($m_1 \neq m_2$), by difference in the lever ($l_{PM1} \neq l_{PM2}$), or by a difference in the mass lever product ($m_1 l_{PM1} \neq m_2 l_{PM2}$).

In a more general example, where the center of gravity of the mass is not lying on the spring axis or the external springs are not coupled to proof masses with the same distance orthogonal to this axis, the acceleration cause a torque in addition to the force in the Z direction. In this case the structure of sensor also rotates. The sensor also includes a transducer to measure the motion of the sensor. For instance capacitive sensing can be performed by means of electrodes on the substrate measuring the capacitance change due to the mass motion.

Single Anchor Accelerometer

FIG. **2** shows a single anchor accelerometer **200** in accordance with an embodiment. The single anchor comprises an anchor A **210**B, two central springs B1 **214**A and B2 **214**B, torsional springs B11 **218**A, B21 **218**B, B12 **218**C and B22 **218**D, rotational levers **216**A and **216**B, DOWN electrodes C11 **220**B and C11 **220**C, and UP electrodes C21 **220**A and C21 **220**D. In this embodiment as is seen there is only one anchor A **210**B that connects the two central springs B1 **214**A and B2 **214**B.

Single Lever Design

FIG. **3** shows a single lever and single anchor accelerometer **300** in accordance with an embodiment.

The spring B **314**B connects the anchor A **310**B to the lever L **316**B. The two external torsional springs B21 **318**B and B22 **318**D connect the end of the lever to the two proof masses PM1 **302**B and PM2 **302**A. The two proof masses are coupled to the substrate with two translating out-of-plane springs.

The two translating springs B11 **318**A and B12 **318**C must be stiff for rotation around X to have the two proof masses moving in anti-phase direction normal to the plane of the substrate. If those springs are compliant for rotation around the X axis then the sensor **300** rotates around X axis.

A linear acceleration cause a force on each of the two proof masses PM1 **302**A ad PM2 **302**B that is transferred to the lever L **316**B and provides a torque on the central spring B **314**B. Moreover, if there is an unbalancing in the mass and lever product then the central spring B **314**B and the lever L **316**B rotate and one of the proof masses moves towards the substrate and the other of the proof masses PM1 **302**A and PM2 **302**B moves in the opposite direction.

Alternative Single Lever Accelerometer

FIG. **4** shows an alternative single lever accelerometer **400** in accordance with an embodiment. The single lever comprises proof masses **402**A and **402**B, anchor **410**B, rotational lever **416**B, translating springs B11 **418**A and B12 **418**C, torsional springs B21 **4188**, B **4148** and B22 **418**D, DOWN electrodes C1 **420**A, and UP electrodes C2 **420**B. As explained in FIG. **3**, the translating springs B11 **418**A and B12 **418**C must stiff for rotation around the X axis to have the two proof masses moving in anti-phase direction normal to the plane of the substrate.

Two MEMS Accelerometers

FIG. **5***a* shows the configuration of the sensor to be a capacitive wheatstone bridge in accordance with an embodiment. FIG. **5***b* shows a configuration for sensing acceleration in a Wheatstone bridge configuration as shown in accordance with an embodiment. FIG. **5***c* shows a configuration for sensing magnetic field in a Wheatstone bridge configuration as shown in accordance with an embodiment. FIG. **5***a* shows the configuration of the sensor to be a capacitive wheatstone bridge in accordance with an embodiment. The sensor **500***a* comprises proof masses **502**A and **502**B, anchors **510**A and **510**B, torsional springs **514**A, **514**B, **518**A, **518**B, **518**C and **518**D, rotational levers **516**A and **516**B, UP electrodes C21 (FIGS. **5***b* and **5***c*) **520**A, C21 (FIGS. **5***b* and **5***c*) **520**D, C22 (FIGS. **5***b* and **5***c*) **520**A and C22 (FIGS. **5***b* and **5***c*) **520**D, and DOWN electrodes C11 (FIGS. **5***b* and **5***c*) **520**B, C11 (FIGS. **5***b* and **5***c*) **520**C, C12 (FIGS. **5***b* and **5***c*) **520**B and C12 (FIGS. **5***b* and **5***c*) **520**C. In response to acceleration the proof masses **502**A and **502**B moves in an anti-phase direction normal to the substrate increasing the capacitance of capacitors C11 and C12 and decreasing the capacitance of the capacitors C21 and C22. For sensing acceleration, the capacitors C11, C21, C12, and C22 can be connected in a Wheatstone bridge configuration as shown in FIGS. **5***b* and **5***c*.

MEMS Accelerometer with Capacitive Readout on Rotational Lever

FIG. **6** shows an accelerometer **600** where a capacitive readout is performed on electrodes on levers instead on proof masses in accordance with an embodiment. The sensor comprises proof masses **602**A and **602**B, rotational levers **616**A and **616**B, anchors **610**A and **610**B, torsional springs **614**A, **614**B, **618**A, **618**B, **618**C, **618**D, UP electrodes C21 **620**A and C21 **620**D, and DOWN electrodes C11 **620**B and **620**C. As is seen, the electrodes **620**A-**620**D are utilized to detect movement of the rotational levers **616**A and **616**B.

MEMS Accelerometer with Tilt Cancellation Paddles

FIG. **7** shows an accelerometer **700** including the tilt cancellation paddles in accordance with an embodiment. The sensor comprises proof masses **702**A and **702**B, torsional springs **714**A, **714**B, **718**A, **7188**, **718**C and **718**D, rotational levers **716**A and **7168**, UP electrodes C21 **720**A and C21 **720**D, DOWN electrodes C11 **720**B and C11 **720**C, and tilt cancellation paddles **722**A, **722**B, **722**C and **722**D. The proof masses **702**A and **702**B move in anti-phase direction normal to the plane of the substrate with the tilt cancellation paddles **722**A and **722**B. The output induced by a tilt between proof masses and the substrate is canceled by measuring the differential capacitance between tilt cancellation electrodes and UP and DOWN electrodes.

Accelerometer and Magnetometer Sensor with Differential Capacitive Sensing

FIG. **8** shows a combined accelerometer and magnetometer sensor in accordance with an embodiment. The combined accelerometer and magnetometer sensor **800** comprises proof masses **802**A and **802**B, anchors **810**A and **810**B, torsional springs **814**A, **814**B, **818**A, **818**B, **818**C and **818**D, magnetic materials **816**A and **816**B, UP electrodes C21 **820**A and C22 **820**D, and DOWN electrodes C11 **820**C and C12 **820**B. The magnetic material induces a torque in response to a magnetic field. This torque will cause the sensor **800** to rotate around x axis. Moreover, acceleration causes the proof masses **802**A and **802**B to move in anti-phase direction normal to the plane of the substrate.

The acceleration and magnetic field can be sensed separately because they cause two different sensing modes, respectively the anti-phase movement of the proof masses and the tilting around the first axis. For instance the combined accelerometer and magnetometer sensor **800** measures by altering the configuration of a capacitive readout on a circuit shown in FIG. **5***b* and FIG. **5***c*. In particular the signals are given by:

$$A_{out} \sim C_{11} + C_{12} - C_{22} - C_{21}$$

$$M_{out} \sim C_{11} - C_{12} + C_{22} - C_{21}$$

where A_{out} is the output given by the acceleration and M_{out} is the output given by the magnetic field.

Placement of Sensing Electrodes when Utilizing a Cap

A cap or a cover provides mechanical protection to a structural layer and optionally forms a portion of an enclosure for the sensor. When utilizing a cap on top of the substrate the sensing electrodes can be located in different areas on the sensor. To describe this feature in more detail refer now to the following discussion in conjunction with the accompanying Figures.

FIG. **9** illustrates a sensor **900** that includes a substrate **906** with a cap **950** coupled thereover with a sensor structure **901** coupled to the substrate by anchor **914** within a cavity **908** of the sensor. In this embodiment, the UP and DOWN electrodes **904**A and **904**B are coupled to the substrate **906**.

FIG. **10** illustrates a sensor **900'** similar to that of FIG. **9** except that the UP and DOWN electrodes **904**A and **904**B are coupled to the cap. FIG. **11** illustrates a sensor **900"** that is also similar to that of FIG. **9** except that an UP electrode **904**A and a DOWN electrode **904**B are on the substrate and there is a DOWN electrode **904**C and an UP electrode **904**D on the cap **950**. FIG. **12** illustrates a sensor **900'"** similar to FIG. **9** except that anchor **914** couples the sensor structure **901** to the cap **950** rather that the substrate **906**. As is readily recognized by one of ordinary skill in the art, for example other embodiments could include on the sensor **900'"** electrodes **904** on both the cap **950** and the substrate **906** or any combination thereof or one up electrode on the cap and one electrode on the substrate or any combination thereof.

ADVANTAGES

The advantages provided by the anti-phase movement of the proof masses normal to the plane are both a high mechanical sensitivity and a high electrical sensitivity. The high mechanical sensitivity is provided because any part of each proof mass is moving by the same amount and so maximizing the inertia that transduces the acceleration in the force causing the proof masses movement. The high electrical sensitivity is provided also by the translating movement because the gap between the proof masses and the electrodes will reduce or increase everywhere by the same amount maximizing the capacitance change that is the output signal of the transducer. Moreover the movement and so the capacitive readout are differential since the proof masses move in anti-phase.

The high mechanical and electrical sensitivity combined provides a variety of other advantages such as high breakout force, high full scale, high signal to noise ratio, or allow to reduce the size of the sensor by keeping similar performances.

Although the present invention has been described in accordance with the embodiments shown, one of ordinary skill in the art will readily recognize that there could be variations to the embodiments and those variations would be within the spirit and scope of the present invention. Accordingly, many modifications may be made by one of ordinary skill in the art without departing from the spirit and scope of the present invention.

What is claimed is:

1. A sensor comprising:
a substrate; and
a mechanical structure, wherein the mechanical structure includes
at least two proof masses including a first proof mass and a second proof mass, and
a flexible coupling between the at least two proof masses and the substrate; wherein the at least two proof masses move in an anti-phase direction normal to a plane of the substrate in response to acceleration of the sensor via an unbalancing torque.

2. The sensor of claim 1, wherein the flexible coupling further comprises:
at least one anchor; and
a torsional system; the torsional system further including an anchoring spring connecting the at least one anchor and a first rotational lever;
a first torsional spring connects the first proof mass to the rotational lever with a first lever length; and a second torsional spring connects the second proof mass to the first rotational lever with a second lever length.

3. The sensor of claim 2, wherein the first lever length and the second lever length of the first rotational lever are different.

4. The sensor of claim 3, wherein the flexible coupling further includes a second anchoring spring connecting the at least one anchor and a second rotational lever;
a third torsional spring connects the first proof mass to the second rotational lever with a third lever length; and a fourth torsional spring connects the second proof mass to the second rotational lever with a fourth lever length;
wherein the second rotational lever rotates counter to the rotation of the first rotational lever in response to acceleration of the sensor.

5. The sensor of claim 4, wherein the third lever length and the fourth lever length of the second rotational lever are different.

6. The sensor of claim 4, further comprising magnetic material, wherein the magnetic material is on any of the at least two proof masses, on the first rotational lever, and the second rotational levers.

7. The sensor of claim 2, further comprising a translational system wherein the translational system includes a first translating spring connecting the at least one anchor to the first proof mass and a second translating spring connecting the at least one anchor to the second proof mass, wherein the first and second translating springs allow motion of the first and second proof masses in a direction normal to the plane of the substrate.

8. The sensor of claim 7, wherein each translating spring comprises a second rotational lever and at least two rotating spring; wherein one of the rotating springs are coupled to the proof mass and other connected to the anchor.

9. The sensor of claim 2, wherein a displacement of the first rotational lever is measured by the transducer via capacitive sensing.

10. The sensor of claim 1, further comprising a transducer for measuring motion of the mechanical structure relative to the substrate.

11. The sensor of claim 10, wherein the motion of the at least two proof masses relative to the substrate is measured by the transducer via capacitive sensing.

12. The sensor of claim 11, wherein the one or more electrodes are located on the substrate.

13. The sensor of claim 11, further comprising a cap, wherein the mechanical structure is located between the cap and the substrate, wherein the one or more electrodes are located on the cap facing the mechanical structure.

14. The sensor of claim 10, wherein the displacement of the coupling springs is measured by the transducer via capacitive sensing.

15. The sensor of claim 1, wherein motion of the at least two proof masses relative to each other are measured by a transducer.

16. The sensor of claim 15, where in the transducer is a capacitive sensor.

17. The sensor of claim 1, wherein the unbalancing torque comprises a difference between a weight of the first proof mass and a weight of the second proof mass.

18. The sensor of claim 1, wherein the flexible coupling includes a lever, wherein the lever has a first length from an anchoring spring to the first proof mass and a second length from the anchoring spring to the second proof mass.

19. The sensor of claim 18, wherein the unbalancing torque comprises either a difference in the first length and the second length or by a difference in a first mass lever product comprising the weight of the first proof mass and the first lever length and a second mass lever product comprising the weight of the second proof mass and the second lever length.

20. A sensor comprising:
a substrate; and
a mechanical structure, wherein the mechanical structure includes
at least two proof masses,
a flexible coupling between the at least two proof masses and the substrate,
a magnetic material;
wherein the mechanical structure rotates around a first axis in response to a magnetic field;
wherein the at least two proof masses move in an anti-phase direction normal to a plane of the substrate in response to acceleration of the sensor via an unbalancing torque.

21. The sensor of claim 20, further comprising a transducer to measure out-of-plane motion of the mechanical structure; and
wherein motion due acceleration and motion induced by magnetic field are measured by the transducer.

22. The sensor of claim 20, further comprises a signal processor to alter configuration of the transducer to switch between measuring motion due to acceleration and motion induced by magnetic field.

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